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RESEARCH ARTICLE

VOLTAGE PROFILE IMPROVEMENT IN A SUBSTATION WITH THE INTEGRATION OF SOLAR POWER: A CASE STUDY ON 33/11KV SUBSTATION BAPATLA

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ABSTRACT

Over the past few years, there has been a notable increase in the integration of PV-based generation into the distribution system. Current developments in renewable energy technologies and modifications to the electric utility. Infrastructures have raised the interest of power utilities in using distributed generation (DG) resources to produce electricity. The latest developments in the utilization and development of distributed generation (DG) resources for power generation applications are contingent upon the deregulation of the electric power industry and the technological limitations of expanding distribution and transmission networks to specific regions. The integration of distributed generation units (DG) into distribution networks has yielded numerous benefits for planners, regulators, and policy makers involved in the electric power system. These advantages are contingent upon the features of distributed generation units (DG), including photovoltaic (PV) and network configuration. This paper provides a thorough analysis of numerous research studies on the technical, financial, and environmental advantages of integrating renewable energy sources, including line-loss reduction, increased reliability, financial gains, and environmental pollution prevention. Here a solar PV unit is optimally sized, placed, and structured to maximize the advantages. The effect of load growth on voltage profile and losses is also studied without and with the integration of PV. The effectiveness of the approach is demonstrated by a case study of the BAPATLA substation. It is discovered that when appropriate measures are made to curb the use of renewable energy, the penetration rate of renewable energy electricity may be effectively increased, in accordance with the principle of economic consumption. For simulation, we are utilizing the MATLAB 2018 version.

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INTRODUCTION

The dynamic energy infrastructure environment necessitates creative solutions to fulfil the increasing demand for reliable and sustainable power systems. The combination of distribution generators, solar energy, and other renewable sources stands out as a game-changing approach among the many promising directions. This introduction lays the groundwork for an in-depth investigation of how various renewable energy technologies, distribution generators, and solar power might work in concert to transform the dynamics of energy use and distribution. Using the sun's plentiful and renewable beams, solar energy has become a strong challenger in the fight for more sustainable and clean energy. Solar photovoltaic technology has advanced to the point where it is now not only a practical but also a more affordable choice for producing electricity. Concurrently, the idea of distribution generators—which are placed in key grid positions—has become more well-known as a way to improve grid resilience, lower transmission losses, and support decentralized power generation. This investigation explores the complex network of opportunities that emerges from the combination of these two exciting components: distribution generators and solar energy. Through the application of modern simulation tools, control tactics, and optimization methodologies, this study seeks to identify potential synergies that could lead to more environmentally friendly, dependable, and efficient. Moreover, the importance of different renewable energy sources keeps growing as the world struggles to make the shift to sustainable energy practices. This research goes beyond solar power and distribution generators to include a wider range of renewable energy sources, such as wind, hydropower, and other environmentally friendly technologies. The comprehensive strategy looks into how different sources can work together to create a robust, adaptable, and sustainable energy future. This investigation attempts to provide insights into the revolutionary potential of solar energy, distribution generators, and renewable sources in influencing the future of energy distribution through a thorough examination of optimization techniques, economic factors, and environmental effects. Our objective as we set out on this journey is to find workable solutions that balance sustainability and economic efficiency, opening the door for a resilient and environmentally conscious energy landscape. In Reference (1) a Newton like method for solving ill-conditioned power systems. Their method showed voltage convergence but could not be efficiently used for optimal power flow calculations. In Reference (2) distribution power flow involves, first of all, finding all the node voltages. From these voltages, it is possible to compute current directly, power flows, system losses and other steady state quantities. Some applications, especially in the fields of optimization of distribution system, and distribution automation (i.e., VAR planning, network optimization, state estimation, etc.), need repeated fast load flow solutions. In Reference (3) improved Backward /Forward sweep load flow algorithm for radial distribution systems which includes the backward sweep and the decomposed forward sweep. Backward sweep uses KVL and KCL to obtain the calculated voltage at each upstream bus. In Reference (4) convergence theorem for a basic type of optimal control problem is explained. In Reference (5) minimum power losses, reliability and voltage profile improvement are obtained by proper allocation of DGs in distribution system based on dynamic programming. In Reference (6) analytical method is proposed to determine the location, size and power factor of renewable DG to minimize energy losses. In Reference (7) DG units can be tied directly to the distribution system or on the customer side of the meter as a way of reducing transmission and distribution losses. In Reference (8) Genetic algorithm is used to minimize the system loss and to improve the voltage profile. To determine the ideal location for PV-based distributed generation, this research proposes a voltage profile enhancement method. PV is utilized as a DG, and in order to lower system losses and enhance voltage profile, the ideal DG source size and location are computed. The results are achieved on the BAPATLA substation, and the load growth factor is also taken into account. This research focused on the best location for PV-based distributed generation in the event of load growth. This paper sectioned into: 1. Mathematical modelling, which includes a single line diagram and a solarPV modelling system; 2. Load growth; 3. Result and discussion comprise the sections of this work.

Mathematical Modelling

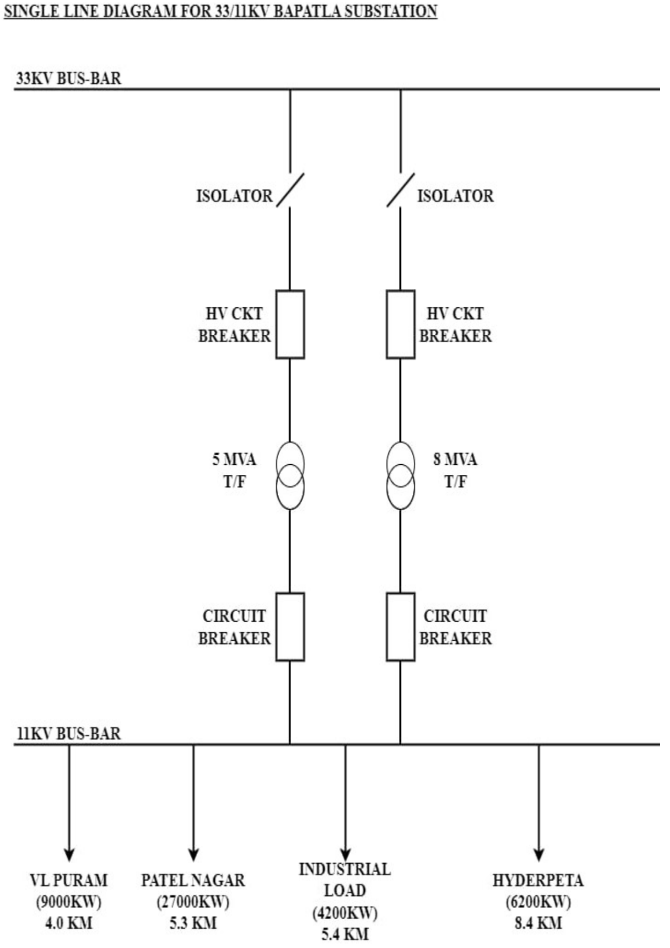

Fig. 1. Single line Diagram for 33/11kv Bapatla Substation

Traditional Methods and System Modelling: Solar PV modelling is used to formulate the load flow problem.

Solar PV Modelling System

Solar Irradience Modelling: An SPV (solar photovoltaic) system is an independent energy generating system, which provides power for different types of devices (9). The power produced by a solar photovoltaic (PV) system can be used straight from the module or stored for later use. However, because solar irradiation varies continuously, PVs are an intermittent source of power. In mathematical analysis, solar irradiance can thus be regarded as a random variable.

To predict the solar irradiation, two approaches based on probability distribution functions are used:

1. Beta solar irradiance modeling
2. The Weibull PDF

Beta Solar Irradiancemodeling

It is the widely used function to model the randomness of solar irradiance the equation which describes the solar irradiance modeling using beta pdf is given by (10)

$$f_{b(s)} = \frac{s^{\alpha-1} * (1-s)^{\beta-1}}{\Gamma(\alpha) * \Gamma(\beta)} (\Gamma(\alpha+\beta)) \quad \ldots\ldots(1)$$

$$\alpha = \frac{\mu * \beta}{1-\mu} \quad \ldots\ldots(2)$$

$$\beta = (1-\mu) * ((\mu * (1+\mu))/\sigma^2 - 1) \quad \ldots\ldots(3)$$

where,

$f_b(s)$=Beta distribution function
s=solar irradiance in w/m^2
α, β=parameter of beta distribution
μ, σ are the mean and standard deviation of solar irradiance.

Modeling of Output power from a solar module: This model is one of best method and widely used to model to output power of a PV module.

The output power of a PV module is given as follows (10)

$$P_{pv} = N*FF*Vy*Iy \quad \ldots\ldots(4)$$

$$FF = V_{mpp} * I_{mpp} / V_{oc} * I_{sc} \quad \ldots\ldots(5)$$

$$V_y = V_{oc} - K_v * T_{cy} \quad \ldots\ldots(6)$$

$$I_y = s\left[I_{sc} + K_i\left(T_{cy} - 25\right)\right] \quad \ldots\ldots(7)$$

$$T_{cy} = T_A + s\left(\frac{N_{OT} - 20}{0.8}\right) \quad \ldots\ldots(8)$$

Where P_{pv}= output power of PV module in Kw

N= No. of module
FF= Fill Factor
V_y= voltage of cell during state 'y'
I_y = current of cell during state 'y'
V_{mpp} = voltage at maximum power point
I_{mpp} = current at maximum power point
V_{oc} = open circuit voltage
I_{sc} = short circuit current
T_c = cells temperature in degree Celsius during state y
K_i, K_v = is the current temperature coefficient A/ °C & the voltage temperature coefficient V/°C
T_A = ambient temperature of cell
N_{OT} = nominal operating temperature of cell
s=solar irradiance in w/m^2

CASE STUDY

A case study is conducted in order to assess the solar irradiation. The study's venue is situated in the Andhra Pradesh state of India's "Bapatla" district. Most people refer to this website as INBOD.

The geographical co-ordinates of the site are (8)

Latitude-15.90 N
Longitude-80.46E
Elevation-6m

For solar irradiance modeling, the long-term monthly average data (TMY(P50)) is utilized as specified in

Table 1. Solar Irradiances (11).

MONTH	GHI(W/m^2)
January	170
February	199
March	257
April	282
May	288
June	273
July	225
August	257
September	227
October	228
November	183
December	163
Yearly average	229.33

The following steps outline the process for use beta modeling to obtain the solar irradiance:

Step 1: Determine the mean (μ) and standard deviation (σ) using the test system data.

Step 2: To find the "α" and "β" parameters, use equations 2 and 3.

Table 2. A tabular representation of the site's yearly mean and standard deviation of solar irradiation is provided

Mean(μ) in KW/m^2	Standard deviation () of solar irradiance (KW/m^2)	Beta pdf parameter(α)	Beta pdf parameter(β)
0.229	0.042	36.30	122.23

STEP 3: Determine the number of samples and the sun irradiance plot. The resultant plot is displayed in

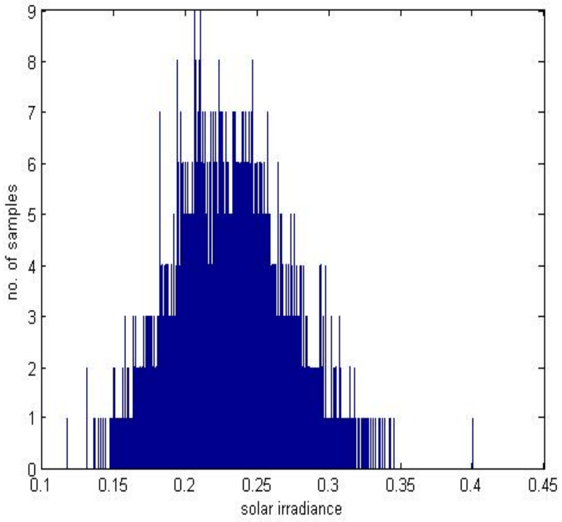

Fig. 2. Solar Irradiance output samples

Modeling of solar output: The methodology for obtaining the solar output is described in following steps.

Table 3. Specifications of cell parameters

N_{OT}	I_{mpp}	V_{mpp}	I_{sc}	V_{oc}	K_i	K_v	N	T_a
45	7.76	30.7	8.72	37.7	0.00349	0.128	1	25

Step 1: Apply equation (5) to the test system data to determine the fill factor value.

Step 2: Determine the output power using (4) using the TMY data(s).

This is the flow chart that shows the output.

RESULTS OBTAINED

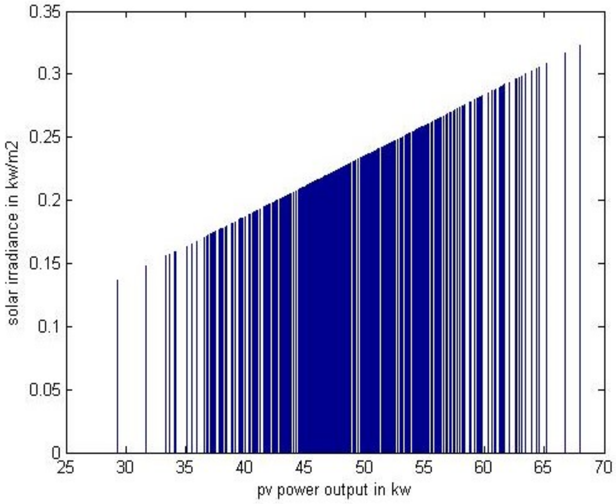

Fig. 3. PV output power profile

Load Growth: In order to develop and expand distribution systems in the future or ensure their proper operation, it is imperative that a system engineer has an estimate of the system solutions that will be needed. For the purpose of future distribution system design and expansion, it is imperative to understand the load growth trend. The load growth has also been taken into account for the PV location in the current work. The suggested load flow technique models load growth as follows:

$$Load_i = \mathrm{Load} \times (1 + \mathrm{r})^{\mathrm{m}}$$

m=plan period up to which feeder can take the load

In this paper work r=0.07 and m=5. The load growth is calculated for all the systems to consider the impact of load growth on PV placement and accordingly the impact on KVAR requirements from PV installed in the system.

RESULT AND DISCUSSION

Loads considered at VL PURAM, PATEL NAGAR, INDUSTRIAL LOAD, HYDERPETA are 9000KW, 27000KW, 4200KW, 6200KW at 0.9 Power factor respectively. Figure 4below makes it rather evident that the voltage profile rises when a photovoltaic (PV) system was built adjacent to bus 3.

There is a lower voltage profile without PV placement. The voltage levels next to bus 3 are raised by the PV panel. However, the inclusion of PV electricity raises voltage levels and increases overall dependability and stability. This improvement emphasizes the need and effectiveness of utilizing renewable energy sources, including photovoltaics, to enhance power distribution system performance and offer consumers a consistent and reliable supply of electricity.

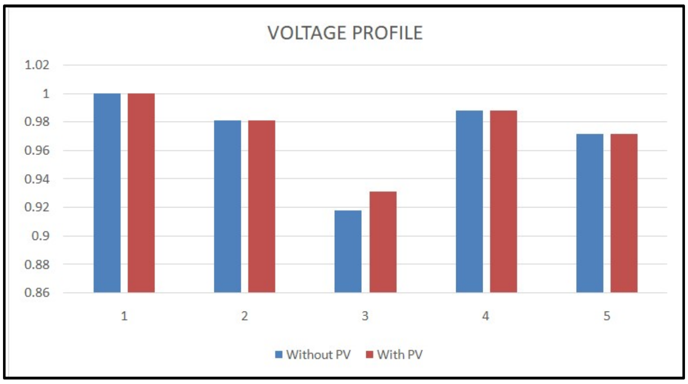

Fig. 4. Voltage profile improvement by placing PV

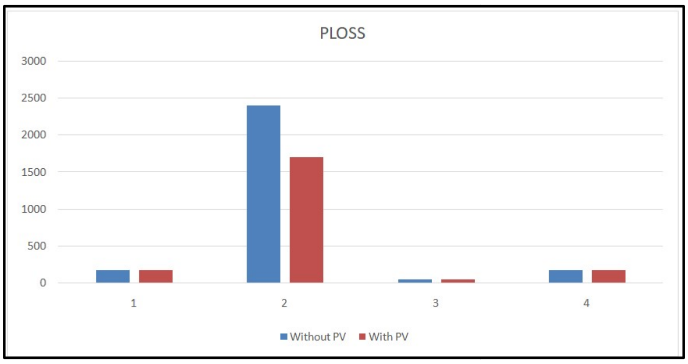

Fig. 5. The above figure displays the ploss

Installing photovoltaic (PV) system close to line 2 helps to lower power losses in the system and improves the voltage profile considerably. Due to variables including increasing reliance on distant power sources and increased resistancealong transmission lines, power losses are often higher in the absence of PV integration. When electricity moves from the source to the load and encounters resistance in the form of heat dissipation, losses like these may happen. But these losses are significantly decreased with the installation of PV systems. This gain can be credited to localized power generation, which minimizes transmission losses by reducing the need for electricity to traverse large distances. PV systems can also run nearer the point of consumption, which lowers distribution losses even further. As a result, adding PV power not only improves the voltage profile but also increases system efficiency by reducing power losses, which eventually results in a more dependable and sustainable power distribution network.

Table 4. Shows the active power and reactive power losses

Losses	Without PV	With PV
Active power	2.80 MW	2.10 MW
Reactive power	1.39 MW	1.04 MW

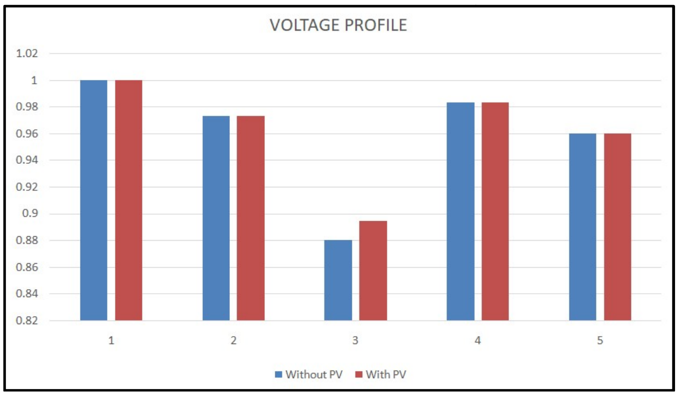

Fig. 6. Voltage profile improvement by placing PV in future load growth

The data displayed in Figure 6 makes it evident how the installation of a photovoltaic (PV) system next to bus 3 increased the voltage profile. The voltage profile stays lower in the absence of PV deployment. The PV panel significantly increases voltage at bus 3. In addition, adding PV power raises voltage levels, which improves overall system stability and dependability.

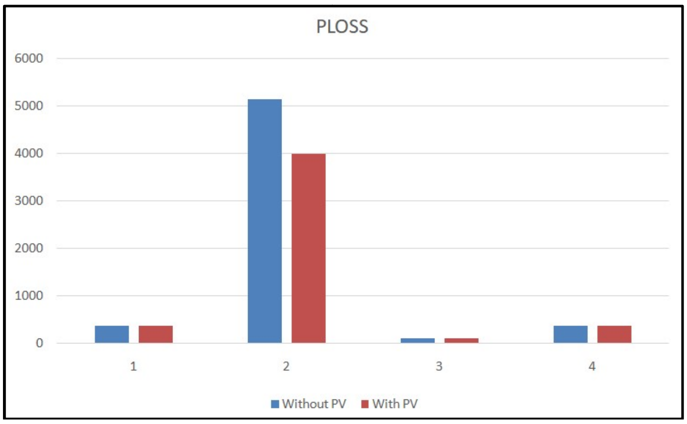

Fig. 7. The above figure displays the ploss in future load growth

Installing photovoltaic (PV) system next to line 2 helps to lower the system's power losses and improve the voltage profile. This enhancement is due to the fact that power is generated locally, which reduces transmission losses by reducing the need for electricity to travel long distances. PV systems can also function nearer the point of consumption, which lowers distribution losses even further.

Table 5. Shows the active power and reactive power losses in future load growth

Losses	Without PV	With PV
Active power	5.95 MW	4.79 MW
Reactive power	2.95 MW	2.38 MW

CONCLUSION

The results collected on the Bapatla substation are presented in this study. It is used to determine the best location for PV-based distributed generation, and beta solar irradiance modeling is used to simulate the PV generator. The Bapatla Substation takes load growth into account when making future plans. The purpose of integrating PV-based distributed generation (DG) into the system is to enhance the voltage profile, minimize power losses under constant load, and account for load growth. From this it is concluded that losses are reduced and voltage profile is improved with PV-based DG comparing to without PV-based DG.

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